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STATE AGRICULTURAL COLLEGE.

ZOÖLOGICAL DEPARTMENT.

HONEY ANALYSES

BY A. J. COOK.

The Bulletins of this Station will be sent free to all newspapers in the State, and to such individuals interested in farming as may request it. Address all applications to the Secretary, Agricultural College, Michigan.

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HONEY ANALYSES.

The subject of honey adulteration is one of great importance to bee keepers. It is generally believed that adulteration is very common. One of the leading chemists of the country has affirmed that probably one-half of the extracted honey in our markets is more or less adulterated. It has generally been thought by bee keepers, and with good reason, that if honey was so extensively adulterated it was the work almost exclusively of the dealers. In fact, in nearly all cases where analyses have shown honey to be adulterated, the specimens had the name of some prominent dealers upon them.

There are two very serious objections to this work of adulteration. In the first place it adds largely to the supply of presumable honey in the market, and so lessens the demand for the genuine article; and in the second place, the product is so inferior in quality that its sale must prove very deleterious to the honey market. In nearly all cases the adulterant used is the common starch or commercial glucose. This tasteless substance not only tends to lessen the peculiar honey flavor, but it leaves a metallic taste in the mouth, which is not only very disagreeable, but must in every case tend to destroy the appetite or desire for the genuine article. It is hardly necessary to say that these statements only concern extracted honey, as comb honey is too delicate and fine an article for even the greatest human genius to counterfeit. It will be readily seen, however, that a taint on the fame of any honey is in some sense injurious to all.

There can be hardly any question that with good laws so great an evil could easily be prevented, were we surely able to detect it. This is the more true now, as the bee keepers are thoroughly organized and have formed the Bee Keepers' Union. This organization has the means and the inclination to fight and destroy any evil that confronts the welfare of bee keepers, providing that there is sure proof that the evil exists.

For the last few years there has been great doubt in the minds of many bee keepers whether even our best chemists could surely detect adulteration. The reasons for this were:

1. The report that honey of known purity had been analyzed and pronounced adulterated.

2. That honey is secured by the bees from such varied sources that it was possible that even our best scientists were today unable in all cases to distinguish it from the adulterated product.

3. It is well known that the nectar that the bees gather from the flowers is digested in the honey stomach of the bee as it is being conveyed

to the hive, or possibly by being taken into the honey stomach of the young bees after it is delivered by the gatherers. We know that the nectar is often largely cane sugar, while honey is largely reducing sugar, thus the nectar which the bees gather from the flowers is transformed before it becomes honey. There is hardly any doubt that the secretions from the large compound racemose glands in the head and thorax of bees furnishes the ferment which induces this change.

4. It seems more than likely that when bees gather honey very rapidly (they have been known to gather twenty pounds per colony in a day) that this reduction might be less complete, and so the honey would contain more cane sugar and less reducing sugar than would be found in honey which was produced more slowly. It was thought that this would account for the fact of the varying amounts of cane sugar in different specimens of honey. Again, we find the large glands, already referred to, in both the drones and the queen bees. This fact would argue that honey is not always reduced, and so the queen and drone bees would often have to digest the honey, or a portion of it. It is not at all likely that these bees would possess these glands if all honey was entirely destitute of this cane sugar.

I have the following from Dr. H. W. Wiley, our government chemist, regarding the composition of nectar:

"Referring to my statement in my former letter in regard to the composition of nectar, I think I am strictly correct.

Mr. Alex. S. Wilson, of the Glasgow University, published in the Chemical News, of August 23, 1878, a determination of total sugar in eight kinds of flowers giving also the proportion of fruit sugar, that is invert sugar or reducing sugar, and cane sugar estimated as fruit sugar. The proportions which he found are as follows:

Sugar in Flowers.

	Total. mg.	Fruit. mg.	Cane (as Fruit) mg.
1. Fuchsia, per flower	7.59	1.69	5.9
2. Claytonia alsinoides per flower	0.413	0.175	0.238
3. Everlasting pea, per flower	9.93	8.33	1.60
4. Vetch (Vicia cracca) per raceme	3.16	3.15	0.01
5. Ditto, per single flower	0.158	0.158	----------
6. Red clover, per head	7.93	5.95	1.98
7. Ditto, per floret	0.132	0.099	0.033
8. Monkshead, per flower	6.41	4.63	1.78

Of the eight flowers examined only two contained a larger proportion of cane sugar than of fruit. You see that my statement is absolutely borne out by these analyses.

A very extensive study of the composition of nectar was made by G. Bonnier and published in the Annales des Sciences Naturelles, Vol. 8, page 78. Bonnier also gives references to all preceding works on the composition of nectar. He cites very many I am not able to consult because they extend as far back as 1833.

Speaking of nectaries of plants, he says that in certain circumstances they emit a saccharine liquid called nectar and this liquid contains sugars of two kinds, viz., saccharoses and glucoses. Of the saccharoses which are found in the nectar the principal one is cane sugar. Rarely there is found mélézitose or mannitose. Of the glucoses the most common are dextrose and levulose forming invert sugar. In most cases M. Bonnier observes there is a little more dextrose than levulose.

Braconnot was one of the earlier authors who first pointed out that cane sugar existed in considerable quantities in the nectar of plants. In general, the nectar of plants is a solution of sugars, in which cane sugar, dextrose, levulose and a few other carbohydrates in small quantities are found. It is also more or less acid in its reaction;

very acid in the case of some nectars like those of the Cicer, Lathyrus pratensis and almost neutral in the case of Vicia sativa.

The quantity of water which nectar contains in its natural state is very variable with different kinds of plants and also quite variable in the same kind of plants. In one sample of nectar there was found to be 95 per cent of water while others were found in which there was only a trace of water. The proportion of water usually varies from 60 to 85 per cent.

The total quantity of sugar also varies greatly. The quantity of cane sugar is very variable, according to Bonnier, in different kinds of plants. Its quantity also depends upon the age of the plant. In general the nectars which are extrafloral contain less cane sugar than the floral nectars. The nectars of the Prunus avium and Cratægus oxyacantha contain much less cane sugar than the nectar of the Vicia. The nectar of the Calluna vulgaris contains an extremely small quantity of cane sugar. Cane sugar, on the contrary, is extremely abundant in the nectar of the Mirabilis, Fuchsia and Helleborus niger. From some of these plants Bonnier was able to separate the cane sugar in a pure state by chrystallization. Some analyses of the nectars of different plants made by Bonnier follow below:

Nectar from Lonicera periclymenum.

Water	76.00%
Cane sugar	12.00%
Reducing sugar	9.00%
Dextrin, gums etc.	3.00%

Nectar from Lavandula vera.

Water	80.00%
Cane sugar	8.00%
Reducing sugar	7.50%
Dextrin etc.	4.50%

Nectar from Fritillaria imperialis.

Water	95.00%
Cane sugar	1.00%
Reducing sugar	1.50%
Dextrin etc.	2.50%

In regard to the analysis of honey, Bonnier says that good indications of the character of the nectar secreted by the flowers might be given by the analysis of honey provided the nectar did not suffer considerable modification in its passage through the organism of the bee; but in general, cane sugar, which is quite abundant in the nectar, exists only in very feeble quantities, or not at all, in the honey. He states, however, that in honey from mountainous regions a considerable quantity of cane sugar remains. (Possibly this honey was collected very rapidly, and so not fully digested by the bees. A. J. C.). Also honey harvested in different seasons presents very different characteristics, which often recall the character of the nectar which the bees gathered at the time. The quantity of saccharose in the nectar of the same species of flowers varies within wide limits. In the floral nectaries the maximum proportion of cane sugar in the tissues corresponds to the period when the ovary has reached its development and the fruit has not yet commenced to develop. In all kinds of nectaries, the cane sugar is accumulated as the flower approaches maturity and begins to be destroyed as the organs growing from the flower approach maturity. For this reason, when the amount of saccharose begins to diminish the relative proportion of reducing sugars increases.

It is not by any means certain, however, that at any time in the history of the plant, the sugars might exist in the flower wholly as cane sugar. On the other hand, it is well known that the juices of plants, in nearly all cases where they contain sugar, contain mixtures of various kinds of sugars.

Another reason, which makes plain the abundant appearance of cane sugar during the progress of the life of the plant, is that the cane sugar itself is not directly assimilable by the tissues of the plant, while the invert sugar is assimilable. The result would be that there would be a tendency of the plant to remove from its juices the invert sugar, while the cane sugar would be stored for subsequent employment.

I am aware of the fact that botanists often speak of nectar as sugar, giving the impression that it is cane sugar. Even Gray and Goodale speak of the specific gravity of nectar, and assume that the sugar contained therein is pure cane sugar.

5. It has long been admitted by European as well as American chemists that some honey, especially that from the pine honey dew, was so like honey adulterated with glucose that it was difficult in the present state of the science to distinguish the one from the other. This is probably true of much of the honey that bees secure from the so called honey dew. I have received the following regarding honey dew from Prof. H. W. Wiley:

> "In respect to the honey dew, I did not desire to express any opinion in regard to its origin. I have heard so many conflicting statements on this point that really I am at a loss to form a decision. My own impression is that the plant louse is the primary cause of the exudation, but whether the whole of the honey (would not nectar be a better term?—A. J. C.) exuded passes through the organism of the louse or not is rather a doubtful problem. As you say, the character of the louse itself may have some effect upon the character of the honey produced, but all that the organism of the louse will probably produce on the honey would be in the shape of inversion just as it is inverted in the organism of the bee. It is not probable that the organism of the louse will produce a dextrinoid body from sucrose or invert sugar, although I do not undertake to say that such a change would be impossible."

Because of the above skepticism I commenced some years since to collect samples of honey secured from various kinds of nectar and produced in widely different localities, with the hope that by extended analyses we might arrive at certainty regarding our ability or inability to distinguish genuine from spurious honey. I thus secured honey from several different states, produced from nectar gathered from all the most valuable honey plants, as well as from various kinds of honey dew. Some of the honey was gathered very rapidly. Besides these samples, other samples of honey were adulterated with one-third or one-fourth glucose and still other was stored in clean empty combs, exclusively from pure granulated sugar syrup, and partly extracted the next day and partly after it was capped over. All of these samples were simply numbered and sent to Prof. H. W. Wiley of the Department of Agriculture, and most of them also to Dr. R. C. Kedzie of the Michigan Agricultural College and to Prof. M. A. Scovell, Director of the Experiment Station, Lexington, Kentucky.

In the following table will be found the kind of honey in each of these samples by number and such other data as are of interest in this investigation:

TABLE 1.

No.	Kind.	Locality.	Producer.	Remarks.
1	Basswood	Larrabee Pt., Vt.	J. H. Larrabee	Very fine honey and gathered very rapidly.
2	Sugar Syrup	Agr'l Coll., Mich.	J. H. Larrabee	18 lbs. stored in one night and extracted the next day. Like 29, this was indistinguishable by the taste from first-class honey.
3	Sour Gum	Florida	J. L. Clark.	
4	⅔ Basswood and ⅓ Glucose	Agr'l Coll., Mich.	A. J. Cook	I could readily detect the adulteration by the taste.
5	White Clover	Kentucky	A. C. Cunningham	This was fine honey, but not I think pure white clover.
6	¾ White Clover and ¼ Glucose	Agr'l Coll., Mich.	A. J. Cook	The adulteration was evident from the taste.
7	Unknown	Louisiana		This was of good flavor but never granulated.
8	Basswood	Larrabee Pt., Vt.	J. H. Larrabee	Very excellent and gathered very rapidly.
9	Golden-rod	Agr'l Coll., Mich.	A. J. Cook	Gathered rapidly.
*9	Honey Dew	Agr'l Coll., Mich.	A. J. Cook	Dark and of rank flavor.
10	Horsemint	Texas		Flavor very marked and not agreeable to me.

* No 9 in list of samples sent to Prof. W. A. Scoville.

TABLE I.—*Continued.*

No.	Kind.	Locality.	Producer.	Remarks.
11	Unknown	Louisiana		Rather dark but of pleasant flavor.
12	Oak Acorns	Missouri		From nectar which flowed from insect inhabited acorns. Honey rather pleasant.
13	Mesquite	Pt. Verd, Arizonia.	F. E. Jordan	Light colored with pleasant flavor.
14	Mellissa	Nebraska	H. C. Tyrell	Color light, flavor pleasant.
15	Rocky Mount'n bee-plant	Denver, Colorado	J. L. Peabody	Extracted the same day that it was gathered.
16	Black Mangrove	New Smyrna, Fla.	J. Y. Detwiler.	
17	Horsemint	Texas		Flavor peculiar and not agreeable to me.
18	Willow herb	Petoskey, Mich.	Mr. Case	Very fine in both flavor and appearance.
19	Poisonous (?)	North Carolina		Not poisonous to me.
20	Buckwheat	Agr'l Coll., Mich.	A. J. Cook.	
21	Heart's Ease	Iowa	S. D. Perkins.	
22	Heart's Ease(?).	Iowa		I think this was largely Golden rod.
23	Honey Dew	Agr'l Coll., Mich.	A. J. Cook	From bark lice, very dark and rank; unfit for market.
24	Alsike Clover	Agr'l Coll., Mich.	A. J. Cook	Flavor and appearance both very fine.
25	Heart's Ease	Farragut, Iowa	S. D. Perkins	Light colored with pleasant flavor.
26	White Clover	Middleton, Conn.	Chas. H. Lewis.	
27	Honey Dew	Agr'l Coll., Mich.	A. J. Cook	From Larch Aphides; light colored and pleasant.
28	Fruit Honey	Massachusets		Received from J. H. Larrabee.
29	Cane Syrup Honey	Agr'l Coll., Mich.	J. H. Larrabee	Like No. 2 this was from pure granulated sugar syrup, stored by the bees but not extracted till it was capped over.
30	Mixed Clover and Linden	Agr'l Coll., Mich.	A. J. Cook.	
31	Unknown	Jackson, Mich.		Received fram J. H. Larrabee.
32	White Sage	Filmore, Cal.	J. F. McIntire	Very white and pleasant in flavor.
33	Basswood	Platteville, Wis.	E. France	Said to have been gathered rapidly.
34	Huckleberry	Walton, Mich.	D. C. Leach	Produced on the pine plains.
35	Basswood	Larrabee Pt., Vt.	J. H. Larrabee	Produced rapidly.
36	Red honey	Dubuque, Iowa	Mrs. Louisia Gertenbeck	I have seen such honey gathered from the juice of ripe red raspberries.
37	Mesquite	Pt. Verd, Arizonia.	F. E. Jordan	Fine quality and said to have been gathered quite rapidly.
38	White Sage	Filmore, Cal.	J. F. McIntire	Produced rapidly.
39	Basswood (?)	Farmersville, Mo.	C. A. Spencer	I think too dark and mild for Basswood.
40	White Clover	Madison, Wis.	D. D. Anhien.	
41	Basswood	Madison, Wis.	D. D. Anhien.	
42	Fall honey	Madison, Wis.	D. D. Anhien	Dark colored.
43	Lost in transit.			
44	Honey Dew (comb)	Dayton, Ill.	J. A. Green	Rank flavored; unfit for market,
45	Oak acorn	Missouri		Might have been partly from flowers.
46	Sage	California	Mr. Carey	Said to have been gathered rapidly.
47	Honey Dew	Hamilton, Ill.	Dadant & Son	One year old, dark and rank.
48	Honey Dew	Missouri	Dr. E. C. L. Larch	Very rank and had been "scalded."
49	Honey Dew	Mt. Zion, Ill.	J. S. Hughes	Unfit for market, gathered in 1885.
50	Honey Dew	Illinois	Henry Wilson	Very rank; thought to have been gathered from hickory. Gathered in 1891.
51	Sumach	Norse, Texas	D. N. Clark	Lost in transit.
52	Honey Dew	Martinsville, Mo.	D. E. Keech	Very slow to crystalize, from hickory.
53	Honey Dew	Beaver, Penn.	Wm. L. Barclay	Gathered from oak. A. B. J., Vol. XXV. p. 67. Gathered in 1889.
54	Mixed	Beaver, Penn.	Wm. L. Barclay	Gathered in 1890.
55	Honey Dew	Martinsville, Mo.	D. E. Keech	This was excellent in flavor.
56	Honey Dew	Martinsville, Mo.	D. E. Keech	This was rank and dark.

These samples were all analyzed by the several chemists, and as we had reason to suppose would be the case, the results were surprisingly alike. All the chemists detected the adulteration, but could not distinguish honey dew honey from adulterated honey, nor could they detect honey produced by feeding syrup made from granulated sugar, but classed it with some of the best genuine honey, as suspicious. This product, as will be seen by the analyses, is not simply cane syrup, but transformed cane syrup which has been changed by the bees, much as they change nectar which they collect from the flowers, as they digest it or transform it into honey.

The following are the reports of these several analyses, with the comments of the several chemists who made them.

TABLE NO. 2.—*Report of analyses made by Prof. H. W. Wiley, of the department of agriculture, Washington, D. C.*

Number.	Serial number.	% Water.	% Ash.	Polarization 30°.	% Sugar by inversion.	% Invert sugar.	% Invert sugar in dry substance.	% Sugar in dry substance.	% Total sugar in dry substance.	Polarization at 88°.
1	10784	16.46	0.09	— 3.40	9.84	70.83	84.78	11.78	96.56	15.86
3	10785	19.73	0.08	— 0.60	9.34	65.31	81.36	11.64	93.00	18.54
3	10786	15.80	0.31	—12.30	1.30	70.31	83.50	1.54	85.04	11.53
4	10787	19.23	0.22	+38.30	2.70	60.02	74.31	3.34	77.65	52.83
5	10788	22.02	0.22	—17.10	0.54	67.55	86.62	0.69	87.31	4.63
6	10789	15.19	0.21	+39.70	4.84	65.85	77.65	5.70	83.35	53.53
7	10790	19.22	0.33	—20.00	1.53	69.41	85.92	1.89	87.81	3.81
8	10791	15.30	0.06	— 4.00	6.92	70.74	83.52	8.17	91.69	15.75
9	10792	18.68	0.39	—14.40	0.92	71.39	87.79	1.13	88.92	7.30
10	10793	20.17	0.23	+ 4.50	14.50	73.37	91.91	18.16	100.07	20.08
11	10794	19.15	0.30	— 7.10	2.23	72.04	89.10	2.76	91.84	11.33
12	10795	17.60	0.35	— 1.50	1.77	70.80	85.92	2.14	88.06	19.80
13	10796	18.90	0.15	—13.90	0.54	75.70	93.34	0.66	94.00	6.39
14	10797	17.20	0.19	—10.80	1.54	72.93	88.08	1.86	89.94	11.12
15	10798	18.07	0.58	—14.30	3.01	72.11	88.01	3.67	91.68	7.41
16	10799	22.75	0.35	—23.10	1.39	71.12	92.06	1.79	93.85	— 1.34
17	10800	15.85	0.20	—23.50	3.40	75.42	89.63	4.04	93.67	----------
18	10801	17.15	0.23	— 3.90	3.94	70.74	85.38	4.75	90.13	17.90
19	10802	19.29	0.37	— 5.90	2.55	67.51	83.65	3.15	86.80	14.30
20	10803	16.55	0.28	— 3.15	2.10	73.45	88.02	2.51	90.53	15.50
21	10804	20.07	0.26	—12.70	2.02	70.47	88.16	2.52	90.68	8.20
22	10805	19.59	0.15	—12.20	1.79	72.21	89.80	2.22	92.02	9.70
23	10806	13.76	0.62	+23.10	5.21	61.73	71.58	6.04	77.62	40.30
24	10807	15.70	0.10	— 8.50	3.42	72.80	86.36	4.05	90.41	13.70
25	10808	16.42	0.17	—14.50	1.40	75.56	90.40	1.67	92.07	9.10
26	10809	18.09	0.35	— 9.35	1.48	70.96	86.63	1.80	88.43	12.50
27	10810	15.51	0.12	—10.45	1.40	76.38	90.40	1.65	92.05	11.70
28	10811	18.17	0.20	— 2.50	3.89	69.87	85.38	4.75	90.13	17.20
29	10812	18.36	0.16	— 2.30	7.24	69.84	85.55	8.86	94.41	18.70
30	10813	17.08	0.42	—11.40	1.61	74.97	90.41	1.94	92.35	9.99
31	10814	18.10	0.08	—13.00	1.84	75.70	92.43	2.24	94.67	7.70
32	10815	16.88	0.36	—17.60	3.92	74.54	89.67	4.71	94.38	3.52
33	10816	18.65	0.28	— 8.20	1.46	74.77	91.91	1.79	93.70	12.67
34	11090	17.10	0.39	—17.50	1.40	77.18	93.10	1.68	94.78	3.81
35	11091	17.81	0.27	—10.30	2.84	74.12	90.18	3.45	93.63	10.80
36	11092	20.42	0.45	—12.30	3.40	68.82	86.48	4.27	90.75	8.85
37	11093	17.09	0.10	—15.40	1.45	77.80	93.85	1.76	95.61	6.69
38	11094	15.49	0.18	—14.30	3.48	73.64	87.14	4.11	91.25	8.44
39	11095	17.08	0.64	— 6.40	3.18	71.75	86.53	3.83	90.36	13.80
40	11099	17.88	0.14	—13.40	1.80	75.19	91.56	2.19	93.75	8.24
41	11100	21.57	0.58	—34.50	3.40	70.83	90.31	4.33	94.64	— 8.44
42	11101	22.48	0.61	— 4.40	1.78	67.34	86.87	2.29	89.16	16.20
43	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
44	11134	18.84	0.59	+ 2.60*	2.96	62.74	77.30	3.64	80.94	----------
45	11135	14.44	0.16	—16.60	3.19	75.68	88.45	3.73	92.18	----------
46	11136	16.42	0.18	—18.60	0.87	73.56	88.01	1.04	89.05	----------
47	11137	19.13	0.79	+ 3.60	2.96	66.07	81.70	3.66	85.36	----------
48	11133	18.40	0.53	— 4.30	1.44	67.58	82.82	1.76	84.58	----------
49	11139	17.76	0.46	+ 4.50	1.52	63.86	77.65	1.84	79.49	----------
50	11138	18.52	0.78	+ 4.40	2.65	62.14	76.27	4.47	80.74	----------
51	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
52	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
53	11140	21.94	0.36	—13.50	0.30	66.43	85.10	0.38	85.48	----------
54	11141	19.10	0.15	—11.70	1.14	71.26	88.08	1.41	89.49	----------
55	11153	17.59	1.12	— 3.90	2.27	66.42	80.60	2.75	83.35	----------
56	11154	20.97	0.44	+10.10	5.24	62.46	79.03	6.63	85.66	----------

* All in this column below the asterisk were read at 22° instead of 30°.

U. S. DEPARTMENT OF AGRICULTURE,
Division of Chemistry,
Washington, D. C., December 23, 1892.

Professor A. J. Cook:

Dear Sir—I beg to enclose you a sheet giving the results of our analyses of the samples of honey received from you. Somehow or other, you have omitted numbers 43, 51 and 52. The others are numbered as you sent them, and such information as has been received in regard to them will be found on the sheet.

The more careful examination confirms the preliminary results which I sent you in my letter of the 21st of July last. There are some additional points to which I wish to call your attention.

Prof. Scovell, in looking over my analyses, called my attention to the fact that my No. 9 must be wrong, as it differed so from his No. 9. (It is interesting to note that this was a sample of honey dew honey.—A. J. C.) I then repeated the work with No. 9 and found that it was exactly correct. He therefore suggested that his number and mine were different samples, and at my request he sent me a sample of his No. 9, which as you see is entirely different from mine. The No. 9 of Prof. Scovell polarized at 30° + 12.0; at 88° + 29.85; on inversion at 30° it polarized + 5.5. You will see, therefore, that it is entirely different from the sample entered as my No. 9, and is evidently one of the adulterated honeys, having either received treatment with glucose or else being the product of the aphis from the pine tree. (From plant or scale lice, not necessarily from pine tree aphis, or even aphides.—A. J. C.)

I desire to call your attention further to the samples of honey which at ordinary temperatures show a plus polarization, and which do not have any notable percentage of sucrose. These samples are Nos. 44, 47, 49, 50 and 56. Fifty-six, however, has quite a notable proportion of sucrose. These are samples which show uniformly a low proportion of invert sugar, away below the normal, but are not strongly enough right-handed to indicate that they are mixed with glucose. I am inclined to think that these give us an excellent clue for the detection of the aphis honey when taken especially from the pine trees. (It would be better to omit the words "pine tree" altogether, and say simply honey dew, as most of this honey dew could not have come from pine tree aphides, as there were few or no pines in the regions.—A. J. C.)

I beg to call your attention further to this, that these honeys have uniformly a high content of ash. Added to them is No. 55, which, although it polarizes to the left, has an abnormally low percentage of invert sugar and an abnormally high percentage of ash. I have not yet gotten data enough to make a positive assertion, but I believe that a honey which polarizes to the right at ordinary temperatures, or even slightly to the left, and which has an abnormally low percentage of invert sugar and abnormally high percentage of ash, may be spotted at once as an aphis honey. This I make, of course, guardedly and subject to subsequent correction, but you will see on studying the data, how my results are borne out. For this reason I should be inclined to class the honey No. 23 as a honey dew honey, because of its right-handed polarization (not very great), its high percentage of ash and its abnormally low percentage of invert sugar. Honeys Nos. 4 and 6 both have right-handed polarizations, abnormally low percentages of invert sugar, but the ash is not much above the normal.. These, therefore, would be excluded from the honey dew honeys. I admit that there are other honeys in the list which have a high percentage of ash, viz., No. 39 (this was sent me from Mo. as basswood honey. I questioned the fact, from the taste and appearance of the sample, as will be seen by the table. If it were basswood, it was not unmixed.—A. J. C.), which has so high a percentage as to be suspicious. No. 36 (red honey probably from juice of ripe red raspberries—A.J.C.) likewise with so high a percentage of ash as to be suspicious. But these honeys are strongly left-handed, and therefore could not be positively condemned.

I have added a column of polarizations at 88° temperature for this reason: Invert sugar at that temperature is optically inactive and has no influence on the ray of polarized light. Any polarization, therefore, which a body may have at that temperature, must be due either to sucrose or other optically active bodies. If now we subtract from the polarization of 88° the percentage of sucrose, what is left will indicate the presence of dextrose and other right-handed bodies. In this way it is seen that all suspicious honeys which we examined in this way have an abnormally high right-handed polarization at 88°. This can also be taken as additional evidence of adulteration.

It appears to me that we are well on the road to being able to distinguish louse honey from true floral honey, as we are certainly able to distinguish glucose honey from both.

In regard to the percentage of water permit to say that our determinations were made on one to two grams of the substance in a flat platinum dish, drying from 15 to 20 hours at the temperature of boiling water. There is no more difficult thing than to determine accurately the percentage of water in honey, and while I do not claim that our numbers are absolutely correct yet they are as exact as we could well get them.

The determination of the invert sugar was also made as such by the reduction of the copper, subsequent solution and precipitation of the copper by an electric current, in the metallic state, and calculating the results as invert sugar. The factors having been determined by working on pure cane sugar inverted, as a standard, our results must be practically correct. Other methods of estimating the invert sugar and calculating it as dextrose, or estimating it volumetrically, would lead to different numbers and this must be taken into consideration in looking over these figures.

I had a much more elaborate work planned out for this investigation, but knowing that you are anxious to get these results I transmit them. Hoping that they will be satisfactory to you, I am,

Respectfully,
H. W. Wiley,
Chemist.

I desire to call your further attention to two samples which still show a left-handed polarization at 88°. These are Nos. 16 (Black mangrove honey.—A. J. C) and 41.

It is evident from this behavior that these honeys contain an excess of levulose; that is, they contain more levulose than would naturally be present in invert sugar.'

Sample No. 41 (Basswood honey from Wisconsin.—A. J. C.) has most remarkable qualities. Its still high left-handed polarization at 88° -8.44 indicates that it is something which is very peculiar. If it be pure honey which has been gathered from nectar, it contains an abnormal percentage of levulose. It might be an ordinary honey which was adulterated with a solution of levulose, if such an adulteration is ever practiced. This honey could be made also in another way, that is, by draining granulated honey in which the dextrose part of the invert sugar remains in a solid state and the levulose part runs off. This would be similar to the method of making open-kettle molasses in the South, in which the crystalized sugar is placed in hogsheads with perforated bottoms and the molasses allowed to drain out. Sample No. 41 has evidently been made in one of the ways mentioned above. *At any rate it is an abnormal honey,* (italics mine.—A. J. C.) and I should be glad to know its history when convenient.

In regard to sample No. 16 the same remarks may be applied except with less accentuation.

H. W. W.

TABLE NO. 3—*Results analyses of honey, made by Prof. M. S. Scovell.*

FROM PROF. A. J. COOK.

Number.	Polarization.		Temp. Indirect.	Sucrose.	Reducing Sugars.	Water.	Ash.	Not Determined.	Dialyzed residue pol'rized.	Pollen.
	Direct.	Indirect.								
1	—5.3	—16.3	25	8.35	69.56	13.91	0.69	8.09	1.6	frequent.
2	—1.1	—11.9	25	8.21	66.67	17.65	0.07	7.40	2.0	none.
3	—14.1	—17.25	25	2.43	72.72	13.68	0.19	10.98	3.4	rare.
4	37.6	34.65	25	2.24	62.01	17.08	0.22	18.45	34.5	none.
5	—19.1	—21.45	25	1.78	68.37	19.30	0.16	10.39	0.0	none.
6	38.8	34.0	25	3.65	68.37	12.08	0.23	15.67	34.8	rare.
9	11.9	5.5	25	4.86	65.57	13.33	0.93	15.31	13.2	frequent.
12	—3.5	—6.0	25	1.90	71.43	13.09	0.54	13.04	5.0	frequent.
17	—25.8	—30.0	25	3.19	75.47	12.83	0.17	8.34	—2.0?	none.
21	—5.7	—9.45	25.8	2.86	75.47	15.82	0.16	5.69	2.8	rare.
22	—13.6	—15.95	25	1.78	76.92	15.93	0.14	5.23	—2.0?	none.
24	—1.6	—4.95	25	2.54	76.20	12.50	0.05	8.71	3.8	frequent.
25	—15.8	—18.35	25	1.93	75.47	11.81	0.10	10.69	1.8	present.
26	—2.5	—4.4	25.2	1.44	75.47	13.64	0.19	9.26	1.4	present.
29	—6.0	—11.75	25.2	4.00	73.39	16.80	0.13	5.68	0.7	frequent.
30	—12.8	—15.95	25	2.39	76.19	13.69	0.31	7.42	1.1	frequent.
33	—9.6	—11.9	25.2	1.71	75.47	15.83	0.28	6.71	1.3	present.
34	—20.0	—20.9	25.4	0.68	78.43	16.52	0.23	4.11	—1.6	
37	—17.0	—19.45	24	1.89	80.00	15.52	0.06	2.53	0.3	
39	—9.6	—14.6	23.8	3.78	75.47	15.26	0.36	5.13	0.2	
40	—15.1	—21.0	24	4.46	74.76	16.57	0.09	4.12	-------	
41	—14.4	—17.6	25.2	2.43	72.07	17.72	0.40	7.38	-------	frequent.
42	—14.3	—17.25	24.8	2.24	75.47	18.33	0.11	3.85	-------	none.
43	—16.8	—18.4	24.2	1.23	75.47	14.31	0.06	8.93	-------	
44	—13.2	—16.4	25.2	2.46	74.76	15.77	0.03	6.98	-------	
45	—11.0	—14.4	24.8	2.62	65.57	22.57	0.04	9.20	-------	
46	—13.2	—16.4	24.2	2.45	72.73	14.28	0.02	8.52	-------	
47	—10.4	—15.0	24.8	3.54	74.08	14.65	0.02	7.71	-------	
48	—14.2	—16.9	24.4	2.07	73.39	16.86	0.02	7.66	-------	
49	—10.4	—14.6	24	3.22	72.73	14.30	0.03	9.72	-------	
50	—11.2	—16.4	24	3.99	73.39	14.15	0.01	8.46	-------	
51	—7.7	—16.9	25	7.00	67.79	-------	-------	-------	-------	

KENTUCKY AGRICULTURAL EXPERIMENT STATION,
M. A. SCOVELL, DIRECTOR,
Lexington, Ky., Aug. 6, 1892.

PROF. A. J. COOK, AGRICULTURAL COLLEGE, MICHIGAN:

MY DEAR SIR—I send you enclosed with this letter a tabulated statement of results of the analyses of your honeys, together with some that I had collected and analyzed. These last for the purpose of comparison.

Nos. 1–39 inclusive are your honeys. The numbers are the same as given by you. No. 40 is orange flower honey from Florida. By special request this honey was collected and centrifugaled in the presence of an owner of an orange grove in Florida, who vouches for its purity.

No. 41 I obtained from a can of honey sent to one of the boys here by his mother. The honey was taken from an old hive and was old comb in which the honey had granulated somewhat.

No. 42 is a honey which I took myself from a cap in a hive a few days before the analysis was made. The cap was nearly full, the outer combs only remaining uncapped.

Nos. 43–50 inclusive were honeys gathered around Lexington, although not in my presence, but I have every reason to believe that they were genuine. I made analysis of them last year for Dr. Wiley.

No. 51 is a mixture of 90 per cent of the honey No. 42, and 10 per cent cane sugar.

Explanations: The cane sugar was calculated by the usual formula from the direct and indirect readings of the polariscope. The reducing sugars by Fehling's solution;

water from loss after heating from a lower and then at a temperature of 103° C. for an hour; ash by ignition of the water free residue.

In order to ascertain whether any of the honeys had been mixed with glucose and invert sugar in such proportions that the direct and indirect polarization would indicate a pure honey, 13.024 grams of each honey were diluted with 40 c. c. of water, and dialyzed for 24 hours. This diolyzed residue was then polarized. The readings in the column are given in terms of the normal solution (24.048 grams honey diluted to 100 c. c.). By request Prof. Garman examined the honeys for pollen. His results are given in the column headed pollen. The last honeys you sent came during his absence.

Comments: From the results obtained I am of the opinion that honeys Nos. 4 and 6 are adulterated with glucose. I reach this conclusion from the fact: First, that they are strongly right-handed honeys; second, that there is a large amount of undetermined matter in them; third, that after dialysis the residue still polarizes strongly to the right. The ash also is in excess of what it generally is in pure honeys.

Honeys 9 (honey dew honey.—A. J. C.) and 12 (honey dew honey —A. J. C.), and 1 (most excellent basswood honey.—A. J. C.) and 2 (sugar syrup honey.—A. J. C.) are difficult to classify. Nos. 9 and 12 might be adulterated with a small quantity of glucose or they might be natural honeys of the "pine tree order." *The ash of each appear to be abnormally large.*

The indications are that honey Nos. 1 and 2 have either been adulterated with about ten per cent of cane sugar or the bees have been fed cane sugar. *With our present knowledge* (italics mine—A. J. C.), however, I would not positively state that they were sophisticated honeys. That a genuine honey might be adulterated with ten per cent of cane sugar and have the composition of honeys Nos. 1 and 2 may be readily seen by reference to the adulterated honey No. 51.

Honeys Nos. 5, 17, 34 and 37 (all genuine honey.—A. J. C.), polarize more than ordinarily to the left, but if invert sugar has been added to any of the honeys I have been unable to detect it.

Honey No. 3 was fermenting when received and some of it had leaked out. Honeys Nos. 34 and 39 were received in bad condition. The combs were nearly drained when they were unpacked.

I hope these results may be of interest to you and throw light upon this most important question. If you have any more honeys to send I will be glad to investigate them. I hope the work may be continued until the problem is solved.

Yours very truly,
M. A. Scovell.

The following are the results of the analyses made by Dr. R. C. Kedzie at the College:

ANALYSIS OF HONEYS.

By direction of the State Board of Agriculture a collection of honeys—pure and adulterated—furnished by the zoölogical department, were analyzed to test the question whether chemical analysis can distinguish between genuine and adulterated honeys. The same honeys were sent to Prof. H. W. Wiley, chemist of the department of agriculture, and Prof. M. A. Scovell, of the Kentucky experiment station. The results of these three parallel analyses were compared in Washington, and the adulterated honeys were detected in every genuine honey (*i. e.*, material made from the nectar of flowers), and doubt was entertained only in abnormal honeys, *e. g.*, honey made from the secretions of plant lice.

The following table shows the results of analysis of all the samples furnished, a few numbers being blank because the specimen was not furnished:

TABLE NO. 4.—*Analyses of honeys from Prof. A. J. Cook.*

Number.	Poplarization.		Temperature (centigrade.)	Sucrose, per ct.	Reducing sugar, per ct.	Water, per ct.	Undetermined, per ct.	Remarks.
	Direct.	Indirect.						
1	—6.16	—13.2	20°	5.32	69.	14.68	11.0	
2	1.76	—12.3	20°	7.95	75.	14.90	2.15	
3	—11.4	—13.2	20°	1.36	68.6	15.25	14.79	
4	36.4	32.8	20°	1.20	58.3	18.8	21.70	Precipitate of dextrine.
5	—14.5	—20.2	20°	4.30	68.3	21.2	6.20	
6	38.7	35.6	20°	2.34	58.0	15.20	24.46	Precipitate of dextrine.
7	—18.9	—26.4	20°	5.66	68.9	18.1	7.34	
8	—5.72	—14.9	20°	6.94	70.7	15.1	7.26	
9	.0	—5.	20°	.37	67.3	14.9	7.34	
10	—1.76	—4.4	20°	1.99	71.9	19.6	6.51	
11	—7.9	—22.8	20°	11.20	73.6	14.70	.50	
12	—4.4	—7.4	20°	2.26	71.8	15.9	10.04	
13	—14.9	—15.4	20°	.37	75.3	18.2	6.13	
14	—8.8	—11.8	20°	2.26	73.5	12.83	11.41	
15	—18.9	—22.6	20°	2.79	73.1	15.08	9.03	
16	—17.6	—18.4	20°	.60	70.6	18.52	10.28	
17	—24.2	—27.2	20°	2.26	77.6	14.8	5.32	
18	—3.08	—6.80	20°	2.80	69.7	13.44	14.06	
19	—5.7	—9.2	20°	2.64	67.7	14.49	15.19	
20	—18.4	—19.3	20°	.68	70.5	12.90	15.92	
21	—7.04	—10.5	20°	2.64	75.1	17.60	4.66	
22	—10.5	—15.4	20°	3.70	71.7	18.3	6.30	
23	22.	13.2	20°	6.64	58.2	13.4	21.76	Precipitate of dextrine.
24	—9.2	—15.4	20°	4.68	76.8	13.3	5.22	
25	—13.2	—19.7	20°	4.91	74.1	14.9	6.09	
26	—16.2	—18.4	20°	1.66	75.6	19.1	3.64	
27	—10.1	—13.2	20°	2.34	80.1	15.4	2.16	
28	—1.32	—8.8	20°	5.64	67.8	15.6	10.96	
29	—1.76	—11.0	20°	6.22	60.2	17.3	16.28	
30	—11.	—14.08	20°	3.77	78.2	15.8	2.23	
31	—11.8	—15.4	20°	2.71	68.1	16.5	12.69	
32	—15.7	—23.7	20°	6.79	68.8	16.1	8.31	
33	—7.4	—11.	20°	2.71	75.1	18.6	3.59	
34	—18.4	—23.3	20°	3.70	78.5	12.10	5.70	
35	---------	---------	20°	---------	---------	---------	---------	
36	---------	---------	20°	---------	---------	---------	---------	
37	—15.4	—17.6	20°	1.66	75.2	16.6	6.54	
38	—13.2	—22.	20°	6.64	60.5	15.9	16.96	
39	—6.6	—11.0	20°	3.32	68.8	17.6	10.28	
40	---------	---------	---------	---------	---------	---------	---------	
41	---------	---------	---------	---------	---------	---------	---------	
42	---------	---------	---------	---------	---------	---------	---------	
43	—11.0	—13.2	20°	1.66	75.0	15.3	8.04	
44	---------	---------	---------	---------	---------	---------	---------	

R. C. KEDZIE, *Chemist.*

CONCLUSIONS.

These analyses show conclusively that our chemists can easily distinguish honey adulterated with glucose, the only adulterant that is likely to be used, from all honey except that produced from honey dew. All three chemist at once detected the two samples which were adulterated, the one with one-fourth, the other with one-third of the common commercial glucose of the shops. These samples gave a right-handed rotation, and a precipitate of dextrine. The samples were numbers 4 and 6.

It is also shown that previous to this time our best chemists could not distinguish between adulterated honey and some kinds of honey dew honey. Thus Prof. Wiley and Dr. Kedzie grouped No. 23 with Nos. 4 and

6 as adulterated, and Prof. Scovell did the same with No. 9 in his list. It is to be hoped that the careful analyses of Prof. H. W. Wiley have given us a means of separating the rank honey dew honey from the adulterated article. Although this is not a matter of great practical importance, for such honey will never be placed on the markets, in competition with other honey, yet it is very desirable that the chemist shall be able to distinguish all adulteration. If a large percentage of ash, and a relatively small proportion of invert sugar, together with a right-handed or slight left-hand rotation is a sure indication of honey dew honey, then surely that fact alone is worth many times the expense and trouble which these investigations have cost. These analyses also clearly show that the term pine tree honey is a misnomer, and that the term honey dew honey should be used in its stead, for honey produced from secretions of aphides, as the honey dew in question was from other aphides than those attacking the pine.

Another interesting fact appears in the analyses of Nos. 12, 45, 27 and 55. All of these were from honey dew. All were pleasant to the taste, and all but one, at most, would pass as genuine honey. They all gave a right-handed rotation, a large amount of invert sugar, and a small amount of ash. They would all be pronounced genuine honey by the chemists and by the consumer. Will not Prof. Wiley then have to modify his definition of honey? Is it necessarily transformed nectar from flowers? Is it not more in harmony with truth to call it transformed nectar, and confess that there may be grades of honey which we all know to be true. Because the cow has eaten leeks, shall we say that the product of the churn is not butter? Let us tell the truth, and shame the timid soul, by taking what I believe is the only defensible ground, that any liquid product of bees is honey; that some honey of excellent quality was not produced from the nectar of flowers, and that the quality will vary with the source of the nectar. Nectar must pass into the honey stomach of the worker bees, and then be returned to the honey cells to produce honey and this is honey whatever the source of the nectar. Any other definition clearly makes it impossible to guarantee any honey as genuine. These analyses make this clear, as Nos. 12, 27 and 45 were entirely unsuspected by the chemists, and yet each had its chief source in honey dew.

This is further emphasized in what Prof. Wiley says on page 10 regarding No. 41. This was basswood honey from Wisconsin, of most excellent quality, yet he pronounces it abnormal. Probably it was slightly mixed with other honey. There are points in which chemists who are not physiologists or apiarists are likely to err. They do not take into account the completeness of digestion. Thus numbers 2 and 29 were both pure sugar syrup honey, and yet so different that the chemist would not suppose them of like origin. One was extracted at once while the other was permitted to remain in the hive till it was capped over. It was more fully transformed. It is quite possible that the same honey gathered rapidly would give more cane sugar. If so and a chemist should analyze such a sample from a mountain region, he would decide that mountain honey was rich in cane sugar or sucrose. From the fact of admixture, the varied sources of honey and different degrees of digestion, either from being rapidly stored or from being extracted before it was fully ripened, we see we shall not know the full truth till many samples of known origin are analyzed.

It is also interesting that Prof. Wiley grouped Nos. 1, 2, 8, 10 and 27 together because of the abnormal quantities of sucrose. He says of them:

"They would be passed by me as pure, because we are not certain but that in some circumstances bees may not gather honey with this abnormal proportion." He adds further: "No. 10," which was genuine horse mint honey, "seems to be the worst one of the lot, having 14.5 per cent of sucrose. Nos. 1 and 2," genuine basswood and sugar syrup honey, respectively, the latter extracted the day after it was stored, "have nearly ten per cent of sucrose. Nos. 8 and 29," genuine basswood and sugar syrup honey respectively, the latter the same as No. 2, only capped over, "a little over 5 per cent, while normal honeys have usually from .5 to 3 per cent of sucrose only." It is very interesting to observe that the amount of sucrose, or sugar by inversion, in number 29 was only 5 per cent, while that of number 2 was 10 per cent. This shows that digestion or tranformation is not complete when the honey is first stored, but goes on either in the cell or through the young bees taking it again into the stomach, as Mr. Doolittle believes they do, that it may be more thoroughly digested, and then depositing it again in the cells. We see, then, that as yet the chemists cannot distinguish honey from flowers from granulated sugar syrup honey. Prof. Wiley wrote me under date of September 14: "It is true that with our present knowledge of honey chemistry the difference cannot be detected." I will add that as yet I have not found a person that could distinguish the difference by taste, though several experts, including myself, were among the number.

I am certain that no person could distinguish the sugar syrup honey from the genuine, though many think they could do so. It is quite possible that sugar syrup stored out of season might not be so digested or transformed, and the product would not be so very much like the best of honey. Possibly flower nectar honey produced out of season would not be so excellent as we usually find it. Further investigation is required to settle this question.

These investigations, then, prove that as yet our best chemists can not tell sugar syrup honey from the best floral honey. If it is desirable to do so, possibly research may find a method. Undoubtedly most floral honey contains organic extracts, in very small quantities, which may make it possible by very delicate chemical manipulation to distinguish floral from other honey. But if the difference is not perceptible to the taste, and only by the most delicate chemical operations, if at all, I do not see why it is important, though others seem to feel quite differently.

SUMMARY.

We are thus assured by these analysis:

1. That chemists can easily detect adulteration of honey by use of glucose, in all cases where it is likely to be practiced. The same would be true if cane sugar syrup was mixed with the honey.

2. That a probable method to distinguish honey dew honey from honey adulterated with glucose has been determined by these analyses. The right-handed or slight left-handed rotation together with the large amount of ash, and small amount of invert sugar indicate honey dew honey. As honey dew honey will never be put onto the market, this question is of scientific rather than practical importance.

3. As yet the chemist is unable to distinguish between cane sugar syrup honey—by which we mean cane sugar syrup fed to the bees and transformed by them into honey, and not cane syrup mixed with honey, which

is adulteration pure and simple, though a kind not likely to be practiced—and honey from flowers. As the best cultivated taste cannot thus distinguish, this seems of slight importance. If it should prove to be important to be able to distinguish them it is probable that the chemist will discover the means, as chemistry has very delicate eyes, and can usually search out very slight differences.

We see that there are yet unsolved problems in this direction. And it is desirable to follow up the investigations. Prof. H. W. Wiley is desirous to do so till the last fact is discovered. To better accomplish this he desires samples of three or four pounds each of honeys from any *known source*, especially honey dew honey, and that gathered very rapidly. Sugar syrup honey will also be very acceptable. Such samples may be sent to Prof. H. W. Wiley, Division of Chemistry, Department of Agriculture, Washington, D. C. The express will be paid by the Department of Agriculture.

I wish to thank the three distinguished chemists who have rendered such able assistance in determining these valuable results.

A. J. COOK.

AGRICULTURAL COLLEGE, MICH.,
June 29, 1893.